PORTABLE POWER MODULES AND RELATED SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of pending U.S. Provisional Patent Application No. 60/310,860 entitled "PORTABLE POWER MODULES AND RELATED SYSTEMS," which was filed August 8, 2001, and is incorporated herein by reference. This application cross-references pending U.S. Patent Application entitled "AIR DUCTS FOR PORTABLE POWER MODULES," (Attorney Docket No. 243768079US); U.S. Patent Application entitled "CONTAINMENT SYSTEMS FOR PORTABLE POWER MODULES," (Attorney Docket No. 243768080US); U.S. Patent Application entitled "AIR PROVISION SYSTEMS FOR PORTABLE POWER MODULES," (Attorney Docket No. 243768081US); and U.S. Patent Application entitled "FREQUENCY SWITCHING SYSTEMS FOR PORTABLE POWER MODULES," (Attorney Docket No. 243768082US) filed concurrently herewith and incorporated herein by reference.

[0002] background

[0003] The described technology relates generally to portable power modules and, more particularly, to portable power modules trailerable over public roads and capable of providing at least approximately one megawatt of electrical power.

[0004] There are many occasions when temporary electrical power may be required. Common examples include entertainment and special events at large venues. As the demand for energy quickly outstrips supply, however, temporary electrical power is being used in a number of less common applications. For example, as electrical outages occur with increasing regularity,

many commercial enterprises are also turning to temporary electrical power to meet their demands during peak usage periods.

[0005] A number of prior art approaches have been developed to meet the rising demand for temporary electrical power. One such approach is a mobile system that generates electrical power using a liquid fuel motor, such as a diesel fuel motor, drivably coupled to an electrical generator. This system is capable of producing up to two megawatts of electrical power and can be housed within a standard shipping container, such as a standard 40-foot ISO (International Standard Organization) shipping container. Enclosure within a standard shipping container enables this system to be quickly deployed to remote job sites using a conventional transport vehicle, such as a typical tractor truck.

[0006] Temporary electrical power systems that use liquid fuels, such as petroleum-based fuels, however, have a number of drawbacks. One drawback is associated with the motor exhaust, which may include undesirable effluents. Another drawback is associated with the expense of procuring and storing the necessary quantities of liquid fuel. As a result of these drawbacks, attempts have been made to develop temporary electrical power systems that use gaseous fuels, such as natural gas.

[0007] One such attempt at a gaseous fuel system is illustrated in Figure 1, which shows a side elevational view of a power generation system 100 in its normal operating configuration. The power generation system 100 includes a motor 110 drivably coupled to a generator 120. The motor 110 is configured to burn a gaseous fuel, such as natural gas, and is capable of mechanically driving the generator 120 to produce an electrical power output on the order of one megawatt. The motor 110 and generator 120 are housed within a standard 40 foot ISO shipping container 102, which is supported by a trailer 103 having a tandem axle rear wheel-set 104. The trailer 103 can be coupled to

a typical transport vehicle, such as a tractor truck, for movement of the container 102 between job sites.

[0008] Unlike their diesel fuel powered counterparts, gaseous fuel power generation systems of the prior art, such as that shown in Figure 1, have an exhaust gas silencer 114 and a motor coolant radiator 118 installed on top of the container 102 during normal operation. This configuration is dictated by a number of factors, including the size of the gaseous fuel motor 110 and the amount of heat it gives off during operation. The size of the motor 110 reduces the space available inside the container 102 for the exhaust gas silencer 114 and the radiator 118, and the large amount of heat generated by the motor creates an unfavorable thermal environment inside the container for the radiator. Although the exhaust gas silencer 114 and the radiator 118 are installed on top of the container 102 during normal operation, during movement between job sites these components are removed from the top of the container to facilitate travel over public roads.

[0009] A number of shortcomings are associated with the prior art power generation system 100. One shortcoming is the number of transport vehicles required to deploy the power generation system 100 to a given job site. For example, although the container 102 with the motor 110 and the generator 120 inside can be transported to the job site using only one transport vehicle, an additional transport vehicle is also required to carry the exhaust gas silencer 114 and the radiator 118. In addition, once at the job site, a considerable amount of assembly and check-out is usually required to configure the power generation system 100 for normal operation. Both the exhaust gas silencer 114 and the radiator 118 need to be installed on top of the container 102 and the necessary structural and functional interfaces connected and verified. Similar shortcomings arise when it comes time to deploy the power generation system 100 to a second job site. Doing so requires removing the exhaust gas silencer 114 and the

radiator 118 from the top of the container 102, packing the exhaust gas silencer and the radiator for shipment to the second job site, shipping these components and the container separately to the second job site, and then unloading, reinstalling and checking out these components at the second job site.

[0010] Additional shortcomings are associated with the configuration of the prior art power generation system 100. For example, air 131 that has been used to cool the motor 110 and the generator 120 is exhausted out the back of the container 102 because the exhaust gas silencer 114 and the radiator 118 occupy the space on top of the container. The air 131 is warm, thus creating an unfavorable thermal environment around the aft portion of the container 102 for persons or other power modules that function better in cool ambient conditions.

[0011] The foregoing shortcomings of the prior art power generation system 100 offset many of the benefits associated with such a system. Therefore, a temporary electrical power generation system that uses gaseous fuel and has the ability to provide at least approximately one megawatt of electrical power without these shortcomings would be desirable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Figure 1 illustrates an electrical power generation system in accordance with the prior art.

[0013] Figure 2 is an isometric view of a portable power module in accordance with an embodiment of the invention.

[0014] Figure 3 is a top view of the portable power module of Figure 2 taken substantially along line 3-3 in Figure 2 with a roof panel removed for purposes of clarity.

[0015] Figure 4 is a side-elevational view of the portable power module of Figure 2 taken substantially along line 4-4 in Figure 2 with a side panel removed for purposes of clarity.

[0016] Figure 5 is a top view of the portable power module of Figure 2 taken substantially along line 5-5 in Figure 2 with a roof panel removed for purposes of clarity.

[0017] Figure 6 is a side-elevational view of the portable power module of Figure 2 taken substantially along line 6-6 in Figure 2 with a side panel removed for purposes of clarity.

[0018] Figure 7 is an enlarged top view of an air duct in the portable power module of Figure 3 in accordance with an embodiment of the invention.

[0019] Figure 8 is an exploded isometric view of a containment system of Figure 2 in accordance with an embodiment of the invention.

[0020] Figure 9 is an enlarged end view of a motor of Figure 6 taken substantially along line 9-9 in Figure 6 for the purpose of illustrating aspects of a frequency switching system in accordance with an embodiment of the invention.

DETAILED DESCRIPTION

[0021] The following disclosure provides a detailed description of a portable power module that can provide at least approximately one megawatt of electrical power. In one embodiment, this portable power module can be transported as a standard shipping container over public roads, offering a combination of performance and flexibility that can make on-site power generation economically viable for a wide range of applications and users. In addition to common applications in the entertainment and special events fields, this portable power module may offer businesses a cost-efficient safeguard against costly power outages, as well as a reliable means of producing peak-period energy and managing reserve margins. Many specific details of certain embodiments of the invention are set forth in the following description to provide a thorough understanding of these embodiments. One skilled in the relevant art, however, will understand that the present invention may have additional

embodiments, or that the invention may be practiced without several of the details described below. In other instances, structures and functions well known to those of ordinary skill in the relevant art have not been shown or described in detail here to avoid unnecessarily obscuring the description of the embodiments of the invention.

[0022] Figure 2 is an isometric view of a portable power module 200 in accordance with an embodiment of the invention. In one aspect of this embodiment, the portable power module 200 includes a container 202 housing a gaseous fuel motor 210 drivably coupled to a generator 220 that provides electrical power to an electrical outlet 222. When the motor 210 is operating, a horizontally situated radiator 218 connected in flow communication with a motor coolant jacket 212 receives heated coolant from the coolant jacket and returns cooled coolant to the coolant jacket. A rectangular exhaust gas silencer 214 connected in flow communication with a motor exhaust gas manifold 216 receives exhaust gases from the exhaust gas manifold and vertically discharges the gases through an exhaust gas outlet 252 positioned on a top portion 209 of the container 202. In a further aspect of this embodiment, the motor 210, the generator 220, the radiator 218 and exhaust gas silencer 214 are all positioned within the container 202 when the portable power module 200 is in a normal operating configuration. As used throughout this disclosure, the phrase "normal operating configuration" refers to a configuration in which the portable power module 200 can provide at least approximately one megawatt of electrical power.

[0023] In one embodiment, the container 202 has the dimensions of a standard 40-foot ISO certified steel container. As is known, standard 40-foot ISO containers such as this are a ubiquitous form of shipping container often seen on roadway, railway and maritime conveyances. The standard 40-foot ISO container has a length dimension of forty feet, a width dimension of 8 feet and a

height dimension of 8.5 feet. In another embodiment, the container 202 can have the dimensions of what is known as a 40-foot ISO “Hi-Cube” container. The “Hi-Cube” container has a length dimension of forty feet, a width dimension of 8 feet and a height dimension of 9.5 feet. In other embodiments, the container can have other dimensions to suit the particular application. In those applications requiring mobility, the container 202 is supported on a conventional trailer chassis 203 having a tandem axle rear wheel-set 204. A trailer coupling 206 is forwardly positioned on a bottom portion of the trailer chassis 203 for releasably connecting the trailer chassis to a suitable transport vehicle, such as a tractor truck 298, for movement of the portable power module on public roads.

[0024] In one embodiment, an air provision system 228 provides necessary ambient air to the portable power module 200 during operation. The air provision system 228 includes a first air circuit 230 and a second air circuit 240. The first air circuit 230 provides ambient air to a motor compartment 205 through a first air inlet 231 positioned on a first container side 207 and an opposing second air inlet 232 positioned on a second container side 208. This ambient air serves a number of purposes, including cooling the generator 220, providing air to the motor 210 for combustion, and providing general ventilation to the motor compartment 205. As will be explained in greater detail below, a portion of the ambient air entering the motor compartment 205 through the first and second air inlets 231 and 232 exits the portable power module 200 through a first air outlet 233 positioned on the top portion 209 of the container 202.

[0025] The second air circuit 240 draws ambient air horizontally through a third air inlet 241 positioned on the first container side 207 and an opposing fourth air inlet 242 positioned on the second container side 208. This ambient air passes over the radiator 218 before discharging vertically through a second air outlet 243 positioned on the top portion 209 of the container 202. Accordingly, the ambient air provided by the second air circuit 240 convects heat

away from the radiator 218 to lower the temperature of coolant received from the coolant jacket 212 before returning the cooled coolant to the coolant jacket. As will be explained in greater detail below, the container 202 may be adapted to include one or more occluding members optionally positionable over the second air outlet 243 to prevent the ingress of rain or other undesirable substances.

[0026] The portable power module 200 can include various interfaces positioned on the container 202 to operatively and releasably connect the portable power module to other systems. For example, a fuel inlet 250 is provided on the second container side 208 for receiving gaseous fuel, such as natural gas, propane, or methane, from a fuel source 299 and providing the gaseous fuel to the motor 210. A heat recovery system 270 can be provided on the first container side 207 to take advantage of the heat generated by the motor 210. The heat recovery system 270 includes a heat recovery outlet 271 and a heat recovery return 272. Both the heat recovery outlet 271 and the heat recovery return 272 are connected in flow communication to the coolant jacket 212 on the motor 210. In one aspect of this embodiment, the heat recovery outlet 271 and the heat recovery return 272 are releasably connectable to a separate circulation system (not shown) for circulating the hot coolant produced by the motor 210. This hot coolant flows out through the heat recovery outlet 271 and can provide heat for various useful purposes before returning to the coolant jacket 212 through the heat recovery return 272.

[0027] The portable power module 200 of the illustrated embodiment can also include a number of doors for operator access. For example, one or more side doors 260 can be provided so that an operator can enter the motor compartment 205 to operate the portable power module 200 or to provide maintenance. Similarly, one or more end doors 262 can also be provided for operator access to the radiator 218 and related systems.

[0028] A containment system 280 may be disposed adjacent to a bottom portion 213 of the container 202. As will be explained in greater detail below, in one embodiment, the containment system 280 extends substantially over the entire planform of the container 202 to prevent spillage of fluids from the portable power module 200 onto adjacent premises. For example, the containment system 280 may capture fuels or lubricants that may leak from the motor 210 over time. In addition, the containment system 280 may also capture rainwater that has entered the portable power module 200 through the second air outlet 243 or other apertures.

[0029] As those of ordinary skill in the relevant art are aware, different parts of the world use different frequencies of electrical power for their electrical equipment. For example, much of the world (e.g., Europe) uses 50Hz electrical power, while other parts (e.g., the United States) use 60Hz. To accommodate this difference, the portable power module 200 of the illustrated embodiment includes a frequency switching system 290 for switching the frequency of the electrical power output between 50Hz and 60Hz. As will be explained in greater detail below, the frequency switching system 290 includes a turbocharger 211 operatively connected to the motor 210 and having interchangeable components that allow selecting between a 50Hz configuration or a 60Hz configuration. The selected turbocharger configuration determines the speed, or the revolutions per minute (RPM) of the motor 210, which in turn determines the frequency of the electrical power generated by the generator 220. Accordingly, the electrical power provided by the portable power module 200 can be provided in either 50Hz or 60Hz form by selecting the appropriate turbocharger configuration.

[0030] The portable power unit 200 of the illustrated embodiment can use a number of different types of motors and generators. For example, in one embodiment, the portable power module 200 can use a gaseous fuel-burning reciprocating motor, such as the J 320 GS-B85/05 motor manufactured by

Jenbacher AG. In another aspect of this embodiment, the generator can be an HCI 734 F2 generator manufactured by the Stamford Company. In other embodiments, other motors and other generators can be employed.

[0031] In one embodiment, the portable power module 200 can be used to provide temporary electrical power at a remote site as follows. After a customer has placed an order for temporary electrical power, the operator deploys the portable power module 200 to the designated site. Deployment includes releasably attaching the coupling 206 to the transport vehicle 298 and transporting the portable power module 200 to the site. During transport, the various doors (e.g., 260, 262) and covers (e.g., over the first air outlet 233, the second air outlet 243, and the exhaust gas outlet 252) should be closed. Upon arrival at the site, the transport vehicle can be uncoupled from the portable power module 200 and can leave the site. Before operating the portable power module 200, the fuel source 299, such as a natural gas source, is connected to the fuel inlet 250, and the second air outlet 243, the exhaust gas outlet 252, and the first air outlet 233 are uncovered. In this normal operating configuration, the motor 210 can be started and the portable power module 200 can provide at least approximately one megawatt of electrical power to the electrical outlet 222 for use by the customer.

[0032] The portable power module 200 has a number of advantages over the power generation systems of the prior art, such as the prior art system shown in Figure 1. For example, because the fully assembled, operable portable power module 200 fits entirely within a standard 40-foot ISO shipping container, it complies with applicable U.S. Department of Transportation (DOT) standards for travel over public roads. Further, in the embodiment illustrated in Figure 2, the gross weight of the container 202 including its internal components does not exceed 53,000 pounds, and the portion of that 53,000 pounds that is positioned over the tandem axle rear wheel-set 204 does not exceed 34,000

pounds. As a result, the gross vehicle weight of the portable power module 200 combined with the transport vehicle (not shown) will usually not exceed 80,000 pounds, thereby complying with applicable DOT weight standards for travel over public roads. Because of these advantages, the portable power module 200 can be easily deployed to a remote job site over public roads using only a single transport vehicle. In addition, because the major systems associated with the portable power module 200 (e.g., motor 210, generator 220, radiator 218, exhaust gas silencer 214, etc.) are installed within the container 202 in their normal operating configuration, only minimal set-up and check-out of the systems is required at the site before operation.

[0033] A further advantage of the portable power module 200 is that, as presently configured, it can produce at least approximately one megawatt of electrical power while not generating excessive sound pressure levels. For example, the portable power module 200 of the illustrated embodiment is expected to not exceed a sound pressure level of approximately 74 db(A) at a distance of at least approximately 23 feet from the portable power module during normal operation. This ability to attenuate operational noise is attributable to the positioning of the various outlets (e.g., 233, 243, and 252) on the top portion 209 of the container 202 and other noise reduction features. As a result of the relatively low operating noise, the portable power module 200 is compatible for use in populated areas or other applications with noise restrictions.

[0034] A further advantage of the portable power module 200 is provided at least in part by the air provision system 228 that enables the portable power module to produce at least approximately one megawatt of electrical power in a wide range of ambient temperature conditions. For example, it is expected that the portable power module 200 can provide full-rated power at 50Hz in 93 degree Fahrenheit ambient temperature conditions and at 60Hz in 107 degree Fahrenheit ambient temperature conditions. In addition to the foregoing

benefits, the portable power module 200 can also operate on gaseous fuel, such as natural gas, propane, or methane, rather than liquid fuel, such as diesel fuel. This further benefit means that the portable power module 200 may produce less of the undesirable effluents often associated with liquid fuels.

[0035] Figure 3 is a top view of the portable power module 200 taken substantially along line 3-3 in Figure 2, and Figure 4 is a side-elevational view of the portable power module taken substantially along line 4-4 in Figure 2. Portions of the container 202 are shown at least partially removed in Figures 3 and 4 for purposes of clarity. Collectively, Figures 3 and 4 illustrate various aspects of the first air circuit 230 in accordance with an embodiment of the invention.

[0036] As best seen in Figure 3, a first air portion 330 enters the motor compartment 205 through the first air inlet 231 and the second air inlet 232. A first fraction 331 of the first air portion 330 is drawn into a generator air intake 321 to cool the generator 220. This generator cooling air is exhausted out of a generator air outlet 322, as shown in Figures 3 and 4. A second fraction 332 of the first air portion 330 is drawn into a combustion air intake 311 that provides air to the motor 210 for combustion. As shown in Figure 4, the combustion air intake 311 is positioned upstream of the generator air outlet 322 to ensure fresh, cool air is provided to the motor 210 and not the warm air exhausting from the generator air outlet. After combustion, exhaust gases leaving the exhaust gas manifold 216 of the motor 210 pass through a circular exhaust gas duct 312 into the exhaust gas silencer 214 before being vertically discharged through the exhaust gas outlet 252.

[0037] A portion of the air entering the motor compartment 205 through the first and second air inlets 231 and 232 is not drawn into either the generator air intake 321 or the combustion air intake 311. Instead, this portion is used for general ventilation and cooling of the motor compartment 205 and is moved

through the motor compartment by a first air moving system 433 (Figure 4). The first air moving system 433 draws the air from the motor compartment 205 into a rectangular air outlet silencer 434 proximally disposed adjacent to the exhaust gas silencer 214. In one aspect of this embodiment, the first air moving system 433 can be a fan induction system positioned below the exhaust gas silencer 214 just upstream of the air outlet silencer 434. In another aspect of this embodiment, the air outlet silencer 434 is positioned in thermal proximity to the exhaust gas silencer 214 so that air passing through the air outlet silencer passes adjacent to the exhaust gas silencer 214 and convectively reduces the temperature of exhaust gasses passing through the adjacent exhaust gas silencer. Similarly, the proximity of the first air outlet 233 to the exhaust gas outlet 252 promotes mixing of cooling air with exhaust gases to further reduce the exhaust gas temperature exterior of the container 202.

[0038] One advantage of the first air circuit 230 of the embodiment shown in Figures 3 and 4 is the general compactness provided by the arrangement of the respective components. For example, rather than install an exhaust gas silencer on top of the container 202, the portable power module 200 of the present invention mounts the exhaust gas silencer 214 inside the container. As a result, the exhaust gas silencer configuration of the present invention does not require separate transportation to a job site nor does it require the extensive set-up and check-out procedures often associated with prior art systems. Another advantage of the present invention results from locating the exhaust gas silencer 214 in thermal proximity to the air outlet silencer 434 to enhance the reduction of exhaust gas temperatures.

[0039] Figure 5 is a top view of the portable power module 200 taken substantially along line 5-5 in Figure 2, and Figure 6 is a side-elevational view of the portable power module taken substantially along line 6-6 in Figure 2. Portions of the container 202 are omitted from Figures 5 and 6 for purposes of

clarity. Together Figures 5 and 6 illustrate various aspects of the second air circuit 240 in accordance with an embodiment of the invention. Figures 5 and 6 are at least substantially similar to Figures 3 and 4, respectively, except that different components may be labeled for purposes of discussion.

[0040] Referring to Figures 5 and 6 together, the second air circuit 240 includes a second air moving system 643 that draws a second air portion 541 horizontally through the third and fourth air inlets 241 and 242. In one embodiment, the second air moving system 643 includes two fans 644 positioned horizontally above the radiator 218. "Positioned horizontally" as used here means that the fan blades rotate in a plane parallel to the ground. In other embodiments, the fans 644 can be positioned in other orientations as space or function may dictate. The fans 644 draw the second air portion 541 over the radiator 218 to convectively lower the temperature of coolant circulating through the radiator. After passing over the radiator 218, the second air portion 541 is discharged vertically out the second air outlet 243 (Figure 6) located on the top portion 209 of the container 202.

[0041] As best seen in Figure 6, the radiator 218 is connected in flow communication with a coolant circuit 610. The coolant circuit 610 includes a low temperature circuit 611 and a high temperature circuit 614. The high temperature circuit 614 circulates coolant through an oil cooler 615, an intercooler first stage 616, and the coolant jacket 212. The low temperature circuit 611 circulates coolant to an intercooler second stage 612.

[0042] In one embodiment, the second air circuit 240 includes occluding members 646 that are optionally positionable over the second air outlet 243 when the second air circuit is not in use. In the illustrated embodiment, the occluding members 646 are pivoting cover members that are pivotally attached to the top portion 209 of the container 202 adjacent to the second air outlet 243. The occluding members 646 are optionally rotatable between a substantially

horizontal position in which at least a portion of the second air outlet 243 is covered to restrict ingress of rain or other substances and a substantially vertical position in which the second air outlet is substantially open to permit full discharge of the third air portion 541. In one aspect of this embodiment, electrical actuators (not shown) can be interconnected between the occluding members 646 and an adjacent structure, such as the top portion 209 of the container 202, to automatically verticate the occluding members when the motor 210 is started. Similarly, these electrical actuators can be configured to automatically rotate the occluding members 646 back into a closed position when the motor 210 is turned off.

[0043] One advantage of the second air circuit 240 as shown in Figures 5 and 6 is the general compactness provided by the arrangement of the respective components. For example, rather than install a motor coolant radiator on top of the container 202, the radiator 218 of the present invention is permanently installed inside the container. As a result, the radiator configuration of the present invention does not require separate transportation to a job site, nor does it require the extensive set-up and check-out procedures often associated with prior art systems.

[0044] One advantage of the portable power module 200 is the noise reduction resulting from the configuration of the first and second air circuits 230 and 240. As explained under Figures 3 and 4, the first air circuit 230 provides air to the motor compartment 205, and the second air circuit 240 provides air to the radiator 218. By using two air circuits instead of one, the individual air demands of each circuit are necessarily less than the total air demand would be for a single circuit that provided air to both the motor compartment 205 and the radiator 218. As a result, the air flow speeds at the first and second air inlets 231 and 232, and the third and fourth air inlets 241 and 242, can be substantially

lower than prior art systems that use a single air circuit. This reduction in air speed results in a substantial reduction in air noise at the respective inlets.

[0045] A further advantage of the portable power module 200 is the efficiency of radiator cooling it provides. Power generation systems of the prior art, such as those that use diesel fuel, use a single air circuit for both motor compartment and radiator cooling. As a result, with prior art systems either the radiator or the motor will not receive cool ambient air. For example, if the single air circuit first draws outside air through the motor compartment and then passes it to the radiator, then the radiator would receive preheated air. Conversely, if the air was first drawn over the radiator and then passed to the motor compartment, then the motor would receive preheated air. In contrast, the portable power module 200 of the present invention uses two dedicated air circuits, such that both the motor compartment 205 and the radiator 218 are provided with cool ambient air.

[0046] Figure 7 is an enlarged top view of an air duct 700 in the portable power module of Figure 3 in accordance with an embodiment of the invention. In the embodiment shown in Figure 7, the air duct 700 is an air inlet duct mounted to the inside of a container, such as the container 202, in flow communication with an air inlet, such as the first air inlet 231. In one aspect of this embodiment, the air duct 700 introduces ambient air into the motor compartment 205. In other embodiments, the air duct 700 can be used in conjunction with other air inlets or other air outlets for other applications. Although only one air duct 700 is discussed here in connection with the first air inlet 231, another air duct that is at least substantially similar can be used in connection with the second air inlet 232.

[0047] The air duct 700 includes a body 705 that is positionable over the first air inlet 231 to at least partially define a first opening 703 and a second opening 704. The first opening 703 is perpendicular to a first direction 701 and

has an opening dimension 706. The second opening 704 is perpendicular to a second direction 702 that is at least approximately perpendicular to the first direction 701. Accordingly, air flowing into the air duct 700 through the first opening 703 undergoes approximately a 90° direction change before exiting into the motor compartment 205 through the second opening 704.

[0048] In one aspect of this embodiment, the body 705 further defines an overall first body dimension 721 in the first direction 701 and an overall second body dimension 722 in the second direction 702. In a further aspect of this embodiment, the first dimension 721 is less than the opening dimension 706, and the second dimension 722 is greater than the opening dimension. In other embodiments, the first and second dimensions 721 and 722 can have other sizes relative to the opening dimension 706.

[0049] The air duct 700 can include various features to enhance flow performance or reduce acoustic noise in accordance with the present invention. For example, the air duct 700 can include a filter member 712, such as a mesh or a grate, at least substantially disposed over the first opening 703 to prevent the ingress of foreign objects into the motor compartment 205. The air duct 700 can also include an elongate flow splitter 710 longitudinally disposed adjacent to the second opening 704 parallel to the second direction 702 to reduce acoustic noise associated with airflow. Similarly, insulation 730 can be affixed to the flow splitter 710 and to various portions of the body 705, such as the interior of the body, to further reduce acoustic noise.

[0050] A number of advantages are associated with the air duct 700. For example, the low profile of the air duct 700 relative to the cross section of the container 202 enables an operator (not shown) to move freely about the motor compartment 205 with full access to the generator 220. A second advantage of the air duct 700 is the noise attenuation characteristics it provides. The change in direction of the airflow from the first direction 701 to the second direction 702,

in conjunction with the insulation 730 and the flow splitter 710, reduces the flow speed of the incoming air and absorbs the resulting acoustic noise. These features contribute to the relatively low overall sound pressure levels generated by the portable power module 200 during normal operation.

[0051] Figure 8 is an exploded isometric view of the containment system 280 in accordance with an embodiment of the invention. The containment system 280 includes a containment member 804 having a substantially horizontal portion 806 and a plurality of substantially vertical portions 808 that are contiguously attached to the horizontal portion around the perimeter of the horizontal portion. Accordingly, the vertical portions 808 together with the horizontal portion 806 define a containment volume 810 within the containment member 804.

[0052] The containment member 804 is shown outside the container 202 in exploded form in Figure 8 for purposes of clarity. In practice, however, the containment member 804 is at least generally positioned inside the container 202 adjacent to the bottom portion 213. In one aspect of this embodiment, the containment member 804 extends at least substantially over the entire bottom portion 213 inside the container 202 conforming to the interior dimensions of the container. In other embodiments, the containment member 804 can extend over less than the entire bottom portion 213. For example, the containment member 804 can be divided into two or more sections positioned in various locations around the bottom portion 213 as required to meet the needs of a particular application.

[0053] In a further aspect of this embodiment, the containment member 804 is shaped and sized so that the containment volume 810 can contain between 100 and 140 percent of the liquids on board the portable power module 200 (Figure 2) during normal operation. For example, in one embodiment, the containment volume 810 can contain approximately 120 percent of the onboard

liquids. Such liquids may include coolants, lubricants, and water that has either condensed inside the container 202 or has entered through one of the existing apertures. Accordingly, any liquid that may drain or drip from any of the components in the portable power module 200 (Figure 2) will be contained in the container 202 in the containment member 804. In other embodiments, the containment member 804 can be shaped and sized to other criteria as required by the particular application.

[0054] In one embodiment, the containment system 280 can also include one or more drain outlets, such as a drain plug assembly 820, for draining liquids and other substances (not shown) that collect in the containment member over time. The drain plug assembly 820 includes a threaded drain plug 822 optionally threadable into a threaded drain hole 824. When the drain plug 822 is threaded into the drain hole 824, the drain plug assembly 820 is closed such that the contents of the containment member 804 are retained. When the drain plug 822 is removed from the drain hole 824, the drain plug assembly 820 is open such that the contents of the containment member 804 are allowed to drain into a suitable receptacle (not shown). In other embodiments, other types of drain outlets may be employed. For example, one or more valves or petcocks optionally positionable between open and closed positions may be affixed to the containment member 804 for draining collected contents into suitable receptacles. In yet other embodiments, the containment system 280 can be provided without any drain outlets, and thus any collected contents can be removed by other means.

[0055] Figure 9 is an enlarged end view of the motor 210 taken substantially along line 9-9 in Figure 6 for the purpose of illustrating the frequency switching system 290 in accordance with an embodiment of the invention. In one aspect of this embodiment, the frequency switching system 290 allows the frequency of electrical power provided by the generator 220

(shown in Figures 2-6) to be changed by selecting an appropriate turbocharger configuration for the motor 210. The motor 210 includes the combustion air intake 311 that provides the second air portion 332 to an air/fuel mixer 902 to create an air/fuel mixture 952. The air/fuel mixer 902 is connected in flow communication with a driven portion 904 of the turbocharger 211.

[0056] The turbocharger 211 includes a first driving portion 910 that is optionally interchangeable with a second driving portion 911. The driving portion (i.e., either the first driving portion 910 or the second driving portion 911) is mechanically coupled to the driven portion 904. The driven portion 904 compresses the air/fuel mixture 952 received from the air/fuel mixer 902 and introduces it into an adjoining intake manifold 906. The air/fuel mixture 952 passes through the intake manifold 906 into respective combustion chambers in the motor 210 for combustion. Resulting exhaust gasses 962 exit the combustion chambers into the exhaust gas manifold 216. The exhaust gas manifold 216 is connected in flow communication with the driving portion (910/911) of the turbocharger 211. Accordingly, the exhaust gasses 962 flow through the driving portion (910/911) and into the exhaust gas duct 312, thereby transferring kinetic energy to the driving portion which in turn drives the driven portion 904.

[0057] The pressure (or "boost" pressure) of the air/fuel mixture 952 passing from the driven portion 904 into the intake manifold 906 can be controlled by the configuration of the driving portion (i.e., either 910 or 911). In one embodiment, for example, the different driving portions have different rotor configurations that lead to changes in rotational speeds which, in turn, lead to different boost pressures. Different boost pressures result in different motor speeds, which in turn result in different frequencies of electrical power from the generator 220. For example, in one embodiment, a motor RPM of 1500 results

in a generator output of 50Hz and a motor RPM of 1800 results in a generator output of 60Hz.

[0058] It follows from the foregoing discussion that the configuration of the driving portion can be used to control the output frequency from the generator 220. In one embodiment of the present invention, for example, installation of the first driving portion 910 results in a motor RPM of 1500 corresponding to an output frequency of 50Hz, and installation of the second driving portion 911 results in a motor RPM of 1800 corresponding to an output frequency of 60Hz. Therefore, switching from the first driving portion 910 to the second driving portion 911 can change the generator output from 50Hz to 60Hz, and vice versa.

[0059] There are a number of other ways in accordance with the prior art to change the motor RPM, and hence change the generator output frequency, but they lack the advantages of the present invention. Using a throttle valve 914 to vary the rate at which the air/fuel mixture 952 is introduced into the combustion chambers is one such approach to varying motor RPM. However, this approach cannot be used to increase the motor RPM if the throttle valve 914 are already in a fully opened configuration. Another method for controlling output frequency that does not involve changing the motor RPM per se is to interpose a gearbox between the motor 210 and the generator 220. This approach, however, adds weight, complexity, and expense to the portable power module 200. In addition, this approach requires first developing a suitable gearbox. In contrast, the frequency switching system 290 of the present invention can switch between 50Hz and 60Hz generator output by the simple expedient of replacing the first driving portion 910 with the second driving portion 911.

[0060] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from

the spirit and scope of the invention. Accordingly, the invention is not limited except by the appended claims.